# A summary and evaluation of Atlantic salmon (*Salmo salar*) smolt monitoring and rotary screw fish trap activities in the Big Salmon River, 2001 - 2005

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## ABSTRACT

As part of the National Recovery Strategy for the inner Bay of Fundy (iBoF) Atlantic salmon populations, the Big Salmon River in New Brunswick was chosen as a key index river for the monitoring of status and evaluation of various recovery strategies. From May to June 2001-2005, a rotary screw trap (RST) was operated annually near the mouth of the Big Salmon River to monitor emigrating Atlantic salmon smolts. With the exception of 2003, the annual population estimate for both wild and captive-reared $LGB_{parr}$ smolts remained between 4,295-5,969 smolts and 1,691-4,175 smolts, respectively. In 2003, estimates were much higher for the wild (9,200) and $LGB_{parr}$ (6,120) smolts. All values remain considerably lower (<50%) than the estimated mean annual number of smolts, 1966-1971 (20,085 smolts). The annual mean condition factor and age composition of wild, predominantly age-2 smolts in all years, were comparable to values obtained from 1966-1972. DNA analysis of wild smolts in recent years indicates that 38.8% (2003) and 50.0% (2004) were from previous $LGB_{fry}$ distributions (released as $0^+$ unfed fry) and considering the low marine survival of iBoF salmon, unfed fry distributions will continue to be important to the recovery of this salmon population.



## RÉSUMÉ

Dans le cadre de la stratégie nationale de rétablissement pour la population du saumon atlantique de l'intérieur de la Baie de Fundy, la rivière Big Salmon au Nouveau-Brunswick été choisie comme rivière principale pour la surveillance de l'état et évaluer plusieurs stratégies de rétablissement. De mai à juin 2001-2005, une trappe rotative a été mise en œuvre à l'embouchure de la rivière Big Salmon pour faire le suivi de l'émigration des saumoneaux. A l'exception de 2003, la population annuelle estimée des saumoneaux sauvages et saumoneaux élevés en captivité ($LGB_{parr}$), est restée entre 4,295-5,969 et 1,691-4,175 saumoneaux, respectivement. En 2003, l'estimation étaient supérieure pour les saumoneaux sauvages (9,200) et $LGB_{parr}$ (6,120). Ces chiffres demeurent considérablement inférieurs (<50%) à ceux des populations annuelle moyenne estimée des saumoneaux de 1966-1972 (20,085 saumoneaux). Le facteur de conditionnement moyen annuel et l'âge des saumoneaux sauvages, principalement âge-2 durant ces années, étaient comparables aux valeurs obtenues en 1966-1972. Une analyse récente de l'ADN montre que 38.8% (2003) et 50.0% (2004) des saumoneaux sauvages proviennent du type $LGB_{fry}$ (libérés comme alevins 0+ non-alimentés) et considérant la faible survie marine des saumons de l'intérieur de la Baie de Fundy, l'ensemencement des alevins non-alimentés continuera à être important pour le rétablissement de cette population de saumon.

## 1.0 INTRODUCTION

In May 2001 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Atlantic salmon (*Salmo salar*) from the inner Bay of Fundy (iBoF) as "endangered" (COSEWIC, 2001) and in June 2003 iBoF Atlantic salmon were listed under Canada's Species At Risk Act (SARA). While populations of wild Atlantic salmon have declined world-wide in the last couple of decades (ICES, 2003; WWF, 2001) the decline of the iBoF population, which are genetically distinct from neighbouring populations in the Maritime Provinces (Verspoor et al, 2002), has been even more pronounced. Currently, it is estimated that <250 mature Atlantic salmon remain (Amiro, 2003).

Prior to the COSEWIC listing the federal Department of Fisheries and Oceans in conjunction with delegates from other federal and provincial government departments, academia and interested organisations formed a National Recovery Team, which devised a Recovery Strategy (Anon., 2002) in hopes of re-establishing wild Atlantic salmon populations in all salmon producing rivers and streams within the iBoF.

The Big Salmon River in New Brunswick, tributary to the inner Bay of Fundy, was identified as an index river in which a residual population of Atlantic salmon could be monitored and recovery strategies tested. Between 2001 and 2005, the assessment of the residual population of wild Atlantic salmon and an evaluation of release strategies adopted as part of a Live Gene Bank (LGB) program (Anon., 2002; O'Neil et al., 2004) have been carried out using rotary screw traps to monitor emigrating smolts. Smolt monitoring was initiated on the Big Salmon River in 2001 in conjunction with the collection of smolts to study migration patterns in the Bay of Fundy (Lacroix and Knox, 2005 and Lacroix et al., 2005). Smolt monitoring provides information about the status of the iBoF salmon population and with their return as adults, survival conditions at sea.

The following report summarizes the work and information collected during operation of a rotary screw trap(s) on the Big Salmon, 2001-2005. Biological characteristics and population estimates are summarised and where possible, compared with historical data (Jessop, 1975). As well, annual distributions of juvenile salmon from the LGB program are also presented since they contribute to the smolt population in later years. Big Salmon River smolt estimates for 2001, 2002 and 2003 have previously been reported in DFO (2002), DFO (2003) and Gibson et al. (2004).

## 2.0 MATERIALS & METHODS

The Big Salmon River is located in the Province of New Brunswick at 45° 25' 0"N and 65° 24' 0"W (Figure 1).

### *2.1 Rotary Screw Trap Operation:*

A rotary screw trap (RST) consists of an open, 1.54m (diameter) aluminium, conical drum positioned parallel to the water surface and buoyed by two pontoons. The device is anchored in a stream, preferably in an area of constricted, fast flowing water (e.g. at the head of a pool). The

drum may be raised or lowered manually with a mechanical pulley device and when 'set', approximately half of the aluminium drum is submerged in water and the corresponding river flow forces the drum to turn (Figure 2). The turning drum passively catches migrating fish – in this case smolts – and funnels them into a live box at the rear of the RST. A more detailed description of a RST and its uses in other New Brunswick rivers is provided in Chaput and Jones (2004).

With the exception of 2001, one RST (American design[1]) was operated each year at 45° 25' 22.7"N and 65° 24' 35.6"W (Amateur Pool) from the beginning of May to the end of June. In 2001 two RST's were used; one located at the same site above but slightly downstream and the other (Canadian design[2]) was upstream at 45° 30' 57.9"N and 65° 21' 09.3"W (Bridge Pool) for 2 weeks and then downstream at 45° 26' 19.3"N and 65° 25' 02.7"W (Lodge Pool) for the remainder. Daily RST checks included enumerating and sampling all smolts according to protocol (Table 1); catches of all other fish species were documented and released. The RST speed, water and air temperature were recorded each day and hourly water temperatures were measured with a Vemco[3] minilog thermometer during the entire smolt migration period. Mean daily discharges recorded by Environment Canada from the nearby Point Wolfe River have also been included as a proxy for those of the Big Salmon River. Assuming all else being equal (e.g. land utility within the drainage, stream gradient, topography, etc...) the discharges simulated for the Big Salmon River reflect the smaller drainage size of the Point Wolfe River.

*2.2 Live Gene Bank Collections & Distributions and Smolt Sampling Procedures:*

Beginning in 2001, progeny of adult Atlantic salmon removed from the wild as juveniles and raised to maturity in captivity at DFO's Mactaquac Biodiversity Facility (BF) were released at different life stages into the Big Salmon River as part of the Live Gene Bank program. Similarly, the progeny of wild male parr mated with sea-pen-reared female adult salmon in 1998 at the DFO Saint John hatchery were raised to adults at the Province of New Brunswick's Minto Hatchery and spawned (2000 and 2001) to produce progeny for stocking at various life stages in the Big Salmon River, commencing in 2001 (Anon., 2002; DFO, 2003; Gibson et al., 2004). Progeny of Minto spawnings were transferred to Mactaquac BF at the eyed egg stage. In the years following releases this complicated the identification of catches based on their origin (i.e. whether entirely occurring in the wild or spending part of their life cycle in captivity).

Smolts were classified on the basis of the following criteria:

*i.* <u>*Wild smolts:*</u>
- adipose fin present
- no visible signs of fin erosion due to time spent in artificial rearing environment
- exclusion of all LGB candidate parents using microsatellite and subsequent parentage analysis (2003-2005)

[1] E.G. Solutions Inc., Corvallis, Oregon, U.S.A.
[2] Pisces Research Corp., Vancouver, Canada
[3] Vemco Limited, Shad Bay, Nova Scotia, Canada

ii. *Live Gene Bank smolts ($LGB_{parr}$):*
   - adipose fin absent
   - some evidence of fin erosion
   - non-exclusion of all LGB candidate parents using microsatellite and subsequent parentage analysis

iii. *Live Gene Bank smolts ($LGB_{smolt}$):*
   - adipose fin absent
   - fin erosion quite evident (especially dorsal and caudal (upper lobe) fins)
   - size usually much larger than wild and $LGB_{parr}$ smolts
   - coloration often much more pale green and distinguishable from wild or $LGB_{parr}$ smolts

iv. *Live Gene Bank smolts ($LGB_{fry}$):*
   - originally identified as wild smolts
   - later re-classified upon analysis of tissue samples and non-exclusion of all LGB candidate parents using microsatellite and subsequent parentage analysis (2003-2005)

The sampling protocol for all smolts each year was generally the same and only changed slightly when additional information or other projects were incorporated into the smolt activities for the year (Table 1). Sampling included:

- marking a proportion of wild and $LGB_{parr}$ smolts with a dye mark (2001 & 2002) or a numerical streamer tag (2002-2005) for release upstream and recapture to estimate the RST capture efficiency.
- removal of scales, length, weight and tissue for biological characteristics and DNA analysis from a proportion of the wild and $LGB_{parr}$ smolts.

Beginning in 2003, a portion of the wild smolts (~20%) caught in the RST were held and transported to the Mactaquac BF part of the on-going Live Gene Bank program. In large part, these smolts continue to be the basis of the captive reared portion of the Live Gene Bank program, begun with wild parr in 1998 (O'Neil et al., 2004). The smolts are raised to maturity for broodstock and their progeny are distributed annually at different life stages to the Big Salmon River (Table 2) and other iBoF rivers.

Condition factors for wild and $LGB_{parr}$ smolts were determined using $K = 100 \cdot W / L^3$, where W and L are weight (grams) and length (cm), respectively. All wild and $LGB_{parr}$ length-weight ratios for each year were also plotted.

Bayesian mark and recapture methods were used to estimate the population of Atlantic salmon smolts leaving the river annually (Gazey and Staley, 1986). In 2001, smolts were captured, marked and released at the RST operated at either the Bridge or Lodge pools, collectively known as the upper RST (Table 1; Figure 1). Subsequent captures of unmarked and marked smolts in the RST operated at the Amateur Pool (i.e. lower RST, 2001 only) were used to estimate the population. Since only one RST was available for the surveys conducted from 2002-2005, a

method of "recycling smolts" was used. Smolts were captured at the RST operated in the Amateur Pool, marked and then released 3 km upriver just below the Lodge Pool. Recaptures were used to determine the annual smolt population. This method of "recycling smolts" has also been successfully used for estimating smolt populations on the Nashwaak (Jones et al., 2004) and Margaree (Clement et al., 2006) rivers. In 2002 and 2003, additional estimates of RST capture efficiencies were obtained from weekly releases of garment-tagged $LGB_{smolt}$. A different color tag was used each week.

*2.3 Genetic Analyses and Procedures:*

All tissue samples (a caudal fin clip weighing between 5 and 50 mg) collected from live wild smolts for genetic analysis were immediately stored in 1 to 2 ml of 99% ethanol, in 1.5 ml screw cap tubes (Figure 3a). Tissue was then transferred to Qiagen's 96 well DNeasy plates, and DNA extracted and purified following the manufacturer's specifications. DNA was then quantified using Pico Green fluorescent stain from Molecular Probes, and methods given by the manufacturer. DNA concentration was then standardized to 25-50 nanograms per microlitre. Polymerase Chain Reaction (PCR) amplifications were carried out in 10 µl volumes, containing between 50-100 nanograms of template DNA, 2mM each dNTP, 0.5 µM labelled and unlabelled primers, 50mM KCl, 0.5 units of Taq DNA polymerase supplied by MBI Fermentis and 2.0 mM $MgCl_2$. Thermal cycling conditions were as follows: (94°C for 3 min)X1, (94°C for 1 min, 58°C for 30 seconds, 72°C for 30 sec)X5, and (90°C for 30 seconds, 58°C for 30 seconds, and 72°C for 30 seconds)X 30, followed by a 15 minute extension step at 72°C. Primer sequences for loci Ssa197 and Ssa202 are given in O'Reilly et al. (1996) and 2210, 2215, 2216, 1G7 and 1605 are given in Paterson et al. (2002) (Table 3).

*Fractionation, detection and sizing of microsatellite alleles:* PCR products were combined, and salts, unincorporated dNTPs, unincorporated labelled and non-labelled primers removed using Qiagen's 96 well PCR Purification plates, as specified by the manufacturer. Fragments were size fractionated and detected using one of the three following methods: (1) fragment separation on CBS Scientific DNA sequencing apparatus and detection on an FMBIO II, (2) fragment separation and subsequent detection on a Hitachi MJ Research Basestation automated fragment analyser/sequencer, and (3) fragment separation and subsequent detection on an Applied Biosystems 3130 XL. Samples were cross-standardised between platforms and between data sets, by including two individuals from other reference collections (see Figure 3b). One sample from each strip of eight tubes was duplicated in wells 87 to 96 to identify sample placement errors, strip inversions, and plate inversions. Duplication of samples also permitted quantification of rates of genotyping errors.

*Parent-offspring compatibility analyses:* For the most part, each smolt collected in 2003 (208 of 223 smolts) and 2004 (119 of 130 smolts) from the Big Salmon River (Table 4) was compared to the 232 possible candidate crosses (sets of Big Salmon River parents) from 2000, and the 363 possible candidate crosses from 2000 and 2001, respectively (Table 5). Matches between potential sets of candidate parents and offspring (wild-collected smolts) were tested by determining whether a given smolt exhibited one allele from each of the two parents from a given cross at ALL six or seven loci analyzed; smolts collected in 2003 were tested against candidate parents at seven microsatellite loci and smolts collected in 2004 at six microsatellite

loci. Failure of an offspring to match a given cross at all loci analyzed indicated that a smolt was not descended from the set of BSR (Mactaquac or Minto) parents; in such instances, smolts were identified as being produced by wild salmon spawning in river habitat. Instances where a smolt shared one allele with each individual from a given cross at all loci analyzed indicated that the smolt was likely the offspring of the pair of candidate parents. However, it is also possible that the offspring in question matched the set of candidate parents by chance as opposed to by descent, and was actually produced by wild spawning parents.

The combined power of exclusion of the set of six and seven loci analyzed was 0.99959 and 0.99974, respectively. It is therefore unlikely that any individual match between an offspring and a candidate parent-cross was indeed due to the chance sharing of alleles. In fact, given the high power of exclusion of this set of loci, few of the 314 smolts analyzed in 2003 and 2004 matched the candidate parents by chance alone.

## 3.0 RESULTS

### *3.1 Smolt Catches and Biological Characteristics:*

The smolt monitoring program in all five years took place during May and June. The earliest smolts caught in the five years were on May 03, 2002 and the latest on June 29, 2004. It is possible that the smolt run may have already started before the RST was installed in most years. Only in 2005 however, were smolts caught during the first day of operation. The largest annual smolt catches were 1071, 458 and 582 for wild, $LGB_{parr}$ and $LGB_{smolt}$'s, respectively, and all occurred in 2003 (Appendix I). In all years, wild smolts outnumbered both $LGB_{parr}$ and $LGB_{smolt}$ smolts (Figure 4). In 2001, almost half (0.45) of the smolt catch (upper and lower RST catches combined) occurred on 2 days; May 15 and June 04. In the other four years the daily proportion of catch (wild and $LGB_{parr}$ combined) was 0.19 or less of the total catch (Figure 4). Run timing of wild smolts displayed some variability, although with the exception of 2001, 50% of the cumulative wild smolt catch occurred between May 22 and 26 (Figure 5A) and preceded the same value for $LGB_{parr}$ smolts in all years from 2002 to 2005 (Figure 5B).

Wild smolts sampled were predominantly age-2 (Table 6). In 2001 and 2003, <11% of the smolts sampled were age-3, but in 2002, 2004 and 2005 the smolt run was comprised of 26%, 30% and 22% age-3 smolts, respectively. Age-4 smolts represented only 1% of the sampled catch in 2002, 2003 and 2005, while none were sampled in 2001 and 2004 (Table 6). In all years, most of the annual $LGB_{parr}$ smolt migration consisted of age-1 smolts. Age-2 and age-3 smolts represented more of the annual run in 2005 following the LGB age-1 spring parr releases that started in 2003 (Table 2). No age-1 wild smolts were captured in the five years of sampling (Table 6).

Overall mean fork length of wild smolts from 2001-2005 ranged from 14.3 cm ± 1.5 s.d. to 15.8 cm ± 1.5 s.d.. Weight varied between 31.6 g ± 9.4 s.d. and 37.9 g ± 11.1 s.d. (Table 7). Length and weight measurements from the lower RST (at Amateur Pool) in 2001 were not included in these analyses as measurements were for the most part limited to larger smolts selected for an acoustic tagging program (G. Lacroix, DFO St. Andrews) and the length-weight information would therefore have been biased. The $LGB_{parr}$ smolts showed similar results with very little

variation in the fork length or weight between years and the overall size of the $LGB_{parr}$ smolts for each respective age class was smaller than their wild smolt counterparts (Table 7). Annual length-weight graphs are shown in Figure 6, and the overall length-weight equation for wild smolts was $y = 0.014x^{2.8661}$ ($R^2$=0.9098) and for $LGB_{parr}$ was $y = 0.0126x^{2.8769}$ ($R^2$=0.8173). In addition, the overall mean condition factor as determined from the length and weight measurements for wild smolts during the five years was 0.98 (n = 635; range: 0.94 – 1.01) and for $LGB_{parr}$ smolts was 0.93 (n = 309; range: 0.88 – 1.00) from 2002 – 2005 (Table 8).

Other species were also caught in the RST(s) each year. The predominant migratory species captured were American eels (*Anguilla rostrata*), while minnow species (cyprinids including dace and shiners) were the predominant freshwater species. A total of 18 non-indigenous Rainbow trout (*Oncorhynchus mykiss*) were also captured from 2001 to 2005 (Table 9).

*3.2 Genetic Analyses and Live Gene Bank Smolt Collections:*

Locus variability was assessed for the 464 Big Salmon River Mactaquac and Minto candidate parents spawned in 2000 (Table 5). All loci were polymorphic, exhibiting 13 or more alleles (Table 3). Levels of observed and expected heterozygosity were high, ranging from 70.6 to 92.2 and 74.0% to 89.3%, respectively. Differences between observed and expected heterozygosity were small, suggesting that null alleles (alleles that fail to amplify due to mutations in the primer regions) were uncommon and would likely not overly complicate interpretation of results. Later analyses demonstrated that loci would vary considerably in their ability to exclude potential candidate parents (Table 3), and effective heterozygosity seemed a better predictor of information content than did number of alleles.

Beginning in 2003, approximately one in five of the wild (adipose fin present) smolts captured in the Big Salmon River RST were kept for the Live Gene Bank program. The number of smolts added to the Live Gene Bank totalled 223 in 2003, 130 smolts in 2004 and 77 in 2005 (Table 4). Genotype profiles from the six or seven microsatellite markers of the smolts in 2003 revealed that 80 of the 206 smolts analyzed (or 38.8%) were most likely from the $LGB_{fry}$ distributions in 2001 (Table 10). Similar analysis for the 2004 smolts suggests an even greater proportion of wild smolts, about 50%, were also most likely from previous $LGB_{fry}$ distributions in 2001 (age-3) and 2002 (age-2) (Table 10).

Additionally, genetic analyses have provided an estimate of survival for the various LGB distributions at the unfed fry and fall and spring parr stages between 2001 and 2005. For LGB unfed fry reared at Mactaquac (i.e. from Big Salmon River origin parents raised at Mactaquac) the survival to smolt was between 1.4 and 3.6% (Table 2) and that for unfed fry from the Minto hatchery (2001 only) 2.4% (Table 2). Fall and spring LGB parr releases showed survival estimates to the smolt stage ranging from 3.2 – 9.5% (Table 2).

In 2004, a pilot project of 49 wild smolts were implanted with a passive integrated transponder (PIT) to test the impact of tagging smolts on-site (at the RST) and transporting them to the captive component of the Live Gene Bank at the Mactaquac Biodiversity Facility. The PIT tag gives each smolt a unique identifier and allows the combining of run timing (date captured) and biological characteristic data with the genetic information (i.e. origin) without having to process

two tissue samples (i.e. one collected at the RST and one collected at Mactaquac) for the genotype profile. The 2004 PIT tagging experiment incurred 21 mortalities and 5 tag losses as a result of an acute outbreak of flavobacteria/saprolegnia (fungus) and not directly from the PIT tagging or handling procedures. The PIT tagging experiment was continued in 2005. All wild smolts brought to the Mactaquac Biodiversity Facility (n = 77) were first implanted with a PIT tag at the RST and to-date just 6 post-tagging mortalities (<8.0% of the total) have occurred, well within the normal range of loss for rearing in captivity (T. Goff, DFO-Mactaquac, pers. comm.).

*3.3 Annual RST Efficiency and Population Estimates:*

The RST capture efficiencies for the $LGB_{smolt}$'s are shown in Table 11, but were not used to estimate the wild or $LGB_{parr}$ smolt population in their respective years. The annual mean efficiency for untagged $LGB_{smolt}$'s ranged from 0.90% to 4.26% from 2002-2005 and from 1.67% (2002) to 4.27% (2003) for garment-tagged smolts. Weekly differences in capture efficiency of garment-tagged smolts were more variable in 2002 than in 2003.

RST capture efficiencies were also determined for the wild and $LGB_{parr}$ smolts separately, as well as combined (wild + $LGB_{parr}$). Efficiencies for the combined catches from 2002 to 2005 were practically the same, being slightly more than 10% in each of the four years (Table 6). However, when determined separately the efficiencies for the wild and $LGB_{parr}$ smolts were more variable. Chi-square tests between the two smolt groups were performed each year, since efficiency is an essential part in determining the maximum likelihood estimate for the Atlantic salmon population leaving the Big Salmon River. Only 2003 showed a significant difference between the capture efficiency for wild and $LGB_{parr}$ smolts ($X^2 = 5.48$; d.f. = 1; P = 0.05) and therefore the two groups were treated separately in determining their estimate for that year (Table 12).

In 2002 the combined 'estimate' and the respective 'proportion of catch' (for wild or $LGB_{parr}$) from Table 6 were factored together to determine the estimate for each group. Estimates in 2004 were determined in much the same way except that calculations were further divided into two time components based on the relocation of the RST on June 17 and because tests determined the combined efficiencies were significantly different for the two time periods ($X^2 = 42.21$; d.f. = 1; P = 0.05). In this case the estimates for the two time periods, for each smolt group were added to give the final estimate for wild and $LGB_{parr}$ smolts shown in Table 12.

*3.4 Water Temperature, RST Speed and Discharge:*

Overall daily water temperatures varied throughout the smolt monitoring season each year. This trend did not appear different from year to year, with increasing temperatures as the season progressed. From 2001 to 2003 the mean daily water temperature was >10°C by the end of the third week in May, whereas in 2004 and 2005 temperatures remained cooler for longer and did not exceed 10°C until June 04$^{th}$ and May 31$^{st}$, respectively (Figure 4). The average daily mean water temperature for the entire smolt monitoring period was 11.9°C (5.4 – 19.2) in 2001, 10.2°C (3.4 – 15.8) in 2002, 11.2°C (6.1 – 15.1) in 2003, 11.5°C (7.4 – 17.0) in 2004 and 11.3°C (5.9 – 21.1) in 2005.

RST speed which was calculated in revolutions per minute (rpm) and is generally a function of river discharge, was the reverse of temperature and declined throughout the smolt monitoring period while showing daily variability in all years. The highest recorded RST speed in any year was 17 rpm in 2005, while the lowest speed recorded was 2 rpm in 2004 (Figure 7).

Simulated mean daily discharges for the Big Salmon River are shown with the daily proportion of total smolt catch in Figure 8. Like the RST speed, but with less variation, the pattern of discharges steadily receded from their peak in early to mid May. Overall discharges throughout the smolt run were highest in 2005.

## 4.0 DISCUSSION

The origin of Big Salmon River smolts has become increasingly complex in recent years with the distribution of $LGB_{fry}$ and $LGB_{parr}$ ($0^+$ fall parr and $1^+$ spring parr). This has posed some challenges in following the different cohorts and their potential contribution to recovery. Wild smolts or adipose-present smolts are the most complex as they may have originated from wild spawners or from $LGB_{fry}$ distributions, but are virtually indistinguishable without the genotype profiles from microsatellite analyses. This information, combined with biological information such as age and condition factor, provides a solid base for assessing recovery strategies for salmon in the Big Salmon River.

Estimates of smolts were dependent upon the best estimates of capture efficiencies. These differed between wild and $LGB_{parr}$ smolts and the method of tagging. For example, in 2002 and 2003, attempts to use garment tagged $LGB_{smolt}$'s revealed lower capture efficiencies for each of the tagged $LGB_{smolt}$ groups - differentiated by colour - than what was simultaneously being determined for streamer tagged wild and $LGB_{parr}$ smolts. Jones et al. (2004) also observed lower RST capture efficiencies for captive reared smolts released in the spring compared to wild origin smolts on both the Nashwaak and Tobique rivers. It was hypothesized that the $LGB_{smolt}$'s may have been more susceptible to predation due to the relatively large distance between the release locations and the RST and their overall physical attributes like; the considerable fin erosion and overall coloration, which contrasted the natural environment and made them easily visible in the river. It was also possible that on occasion the $LGB_{smolt}$'s were released in the Big Salmon River outside of their 'physiologic' smolt window, which resulted in them remaining in the river rather than leaving for the marine environment (T. Goff, pers. comm., Fisheries and Oceans, Mactaquac; Zydlewski et al., 2005).

Smolt population estimates computed annually suggest that even though the wild smolt population has remained relatively stable in the last five years of monitoring, with the exception of 2003, it remains well below the mean annual estimation of 20,085 smolts from 1966-1972 reported by Jessop (1975).

While the wild emigrating smolts were mostly age-2 in all years, age-3 smolts made up nearly a quarter of the population in 2002 and 2005 and almost one-third in 2004. This compares with what has been observed historically in the Big Salmon River. Jessop (1975) described similar variability in age composition of the smolt run from 1966-1972, but the proportion of age-3 smolts then was typically higher and in three of the years the age-3 smolts comprised more than

half (>55%) of the run. Additionally, wild smolt migration times from 2001-2005 were quite similar to Big Salmon River historical run timing, but overall occurred approximately one week earlier than in 1966-1971 (Figure 5). $LGB_{parr}$ smolts showed a somewhat similar pattern in migration to that of wild smolts, yet 50% of the cumulative catch was not achieved until after the same value for wild smolts was realised, suggesting a possible delay in migration behaviour for $LGB_{parr}$ smolts.

The condition factor of wild and $LGB_{parr}$ smolts ranged from 0.94 to 1.01 and 0.88 to 1.00, respectively and was similar to that of smolts from 1966-1972 (Jessop, 1975). Jessop (op cit) also reported a slight positive relationship between shorter smolt length and increased smolt condition, but smolt data collected from 2001-2005 suggested $LGB_{parr}$ smolts, which were typically smaller than wild smolts (Table 7), displayed a lower mean condition factor each year (Table 8 and Figure 6).

Multilocus genotype profiles of samples collected from wild and $LGB_{parr}$ smolts during the five year period not only allowed for the placement of all individuals into river-specific pedigrees (O'Reilly and Doyle, in press), but it has also provided insight into the efficacy of unfed fry releases as a conservation strategy for the Big Salmon River.

Releasing salmon at this stage is generally more cost efficient and reduces the risk of domestication effects that could otherwise lead to reduced fitness and survival in the wild (Aprahamian et al., 2003). Genotype profiles from the wild smolt tissue samples collected in 2003 (n=223; n=206 analyzed for 6/6+ microsatellite loci) were compared to the genotype data from known parental crosses in the LGB and suggested 38.8% (80/206) of wild smolts were attributed to the unfed fry released in 2001 and leaving the Big Salmon River system as age-2 smolts (Table 10). Likewise, analysis of tissue samples collected in 2004 has shown an even greater proportion of smolts (50%; 54 of 108 analysed) were from previous $LGB_{fry}$ distributions (Table 10). Of these 54 LGB origin smolts, 34 were age-2 and 20 were age-3 (Table 10) and partially accounts for the 20% increase in age-3 smolts from 2003 to 2004 (Table 6). Although preliminary[4], this indicates $LGB_{fry}$ to smolt survival to be in the order of 2% (1.4 - 2.5%; Table 2). Using the $LGB_{parr}$ smolt estimates suggests $LGB_{parr}$ survival to the smolt stage ranges from 3.2 to 9.5% (Table 2). The collection of such information needs to be continued as it is important to implementing and developing future distribution strategies as part of the recovery efforts for iBoF salmon.

There seems to be little doubt that the successful capture of smolts during the spring is dependant on appropriate RST location and environmental conditions that maintain a relatively fast and constant rotation of the RST drum to keep smolts from exiting the trap during operation. Evidence during the five years showed the greatest capture efficiency for combined smolts (wild & $LGB_{parr}$) occurred in 2005 (10.36%; Table 6), the same year RST speed was >5 rpm's for all but 3 days (May 14 & 15 and June 13). In other years such as 2002 and 2004, RST speed was usually <5 rpm's during most of the monitoring period and possibly factored in capture efficiencies less than that in 2005. Additionally in 2004, RST speeds and capture efficiency seemed unusually low and the RST was relocated slightly upstream (~25m) into faster flowing water on June 17. As a direct result of the RST relocation, the RST speed and capture efficiency

[4] preliminary results since some older smolts and those from later year classes have yet to emigrate or be captured

for the remainder of the smolt monitoring period was significantly improved; lending further evidence to the importance of maintaining a constant flow through the RST and the proper position of the RST. The RST speeds in 2001 could not be used for comparative purposes as they were recorded at the upstream RST's, the only year a RST was used in those locations.

The monitoring of smolts in the Big Salmon River over the last five years (2001-2005) has provided important information about the current status and success of ongoing recovery efforts for iBoF Atlantic salmon in New Brunswick. Fisheries and Oceans personnel have collaborated with Fundy National Park staff to expand the smolt program to include the operation of a RST in the Upper Salmon and Point Wolfe rivers (data not reported here) thereby increasing the effort to collect information on iBoF salmon, particularly smolts, and continue the efforts of researchers and interested parties to help re-establish the Atlantic salmon in iBoF rivers. Similar studies warrant continuation, especially in efforts, to monitor the progress of the current recovery program. The smolt monitoring activities also compliment other studies (e.g. of adult returns) and will ultimately play a role in studies looking into the issue of the large marine losses of iBoF salmon, where current knowledge is lacking.

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**Table 1: Sampling procedures by year and origin of Atlantic salmon smolts captured at the rotary screw fish trap(s) operated in the Big Salmon River, 2001 - 2005.**

| Year | Sampling Procedures | | |
|---|---|---|---|
| | **Wild**<br>**** adipose fin present **** | **$LGB_{parr}$**<br>**** adipose fin absent **** | **$LGB_{smolt}$**<br>**** adipose fin absent **** |
| **2001** | • all marked with blue dye on caudal fin at upper and lower RST's<br>• 100 - 150 surgically implanted with acoustic transmitters (G. Lacroix, DFO, pers. comm..)<br>• 20% at upper RST sampled for scales, length and weight<br>• tissue from all acoustic tagged smolts from lower RST's and 20% of smolts from the upper RST | • N/A<br><br>*(Note: No fall fingerlings were released in the Big Salmon River prior to 2001)* | • N/A<br><br>*(Note: No hatchery smolts were released in the Big Salmon River during the spring 2001)* |
| **2002** | • all marked with blue dye on caudal fin<br>• a portion streamer tagged and released 3km upstream<br>• 20% of catch sampled for scales, length, weight and tissue and released downstream<br>• a portion surgically implanted with acoustic transmitters (G.L. Lacroix, DFO, pers. comm.) | • all marked with blue dye on caudal fin, enumerated and released downstream<br>• a portion streamer tagged and released 3km upstream<br>• 20% of catch sampled for scales, length, weight and tissue (for DNA analysis) and released downstream | • all marked with blue dye on caudal fin, enumerated and released downstream<br><br>*(Note: weekly smolt releases were differentiated by coloured garment tags to help identify migration timing)* |
| **2003** | • all tissue sampled for DNA analysis<br>• 20% sampled for scales, length and weight; held and transported to Mactaquac Biodiversity Facility for LGB program<br>• 80% were tagged with numerically sequenced streamer tags, released 3km upstream for mark-recapture experiment | • all tagged with numerically sequenced streamer tags, released 3km upstream for mark-recapture experiment<br>• 20% sampled for tissue, scales, length and weight<br>• percentage of dorsal fin erosion recorded | • all were marked with blue dye on caudal fin, enumerated and released downstream<br><br>*(Note: weekly smolt releases were differentiated by coloured garment tags to help identify migration timing)* |
| **2004** | • 20% sampled for tissue, scales, length and weight; held and transported to Mactaquac Biodiversity Facility for LGB program<br>• 80% were tagged with numerically sequenced streamer tags, released 3km upstream for mark-recapture experiment<br>• 20% of the smolts transported to Mactaquac were implanted with a Passive Integrated Transponder (PIT) tag | • all tagged with numerically sequenced streamer tags, released 3km upstream for mark-recapture experiment<br>• 20% sampled for tissue, scales, length and weight<br>• percentage of dorsal fin erosion recorded | • all were enumerated and released downstream |
| **2005** | • same as 2004, except…<br>• all smolts brought to Mactaquac were implanted with a PIT tag | • same as 2004 | • same as 2004<br><br>*(Note: only 1,296 released)* |

**Table 2:** **Annual distributions and estimated survival to the smolt stage of $LGB_{fry}$ and $LGB_{parr}$ (fall and spring releases) Atlantic salmon captive-reared at Mactaquac Biodiversity Facility, 2000 – 2005 and at Minto Hatchery, 2000 and released to the Big Salmon River as part of the Live Gene Bank program, 2001 - 2005. Note: 2001-2002 distribution data from Gibson et al. (2003); 2003 distribution data from Gibson et al. (2004).**

| Stocking stage | Year of spawning | Year of release (y) | Marked | Captive rearing facility | No. released | Spring parr released | (age-1) smolt estimate (y + 1) | (age-2) smolt estimate (y + 2) | (age-3) smolt estimate (y + 3) | Total smolt output | Total estimated survival to smolt | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fall Parr (0+) | 2000 | 2001 | adipose clip | Mact. | 77,718 | | 2,035 | 1,202 | - | 3,237 | 4.2% | |
| Fall Parr (0+) | 2001 | 2002 | adipose clip | Mact. | 34,062 | 21,025 | 4,918 | 265 | 77 | 5,260 | 9.5% | |
| Fall Parr (0+) | 2002 | 2003 | adipose clip | Mact. | 54,000 | 5,448 | 1,426 | 1,160 | | 2,586 | 4.4% | |
| Fall Parr (0+) | 2003 | 2004 | adipose clip | Mact. | 90,843 | 892 | 2,938 | | | 2,938 | 3.2% | * |
| Fall Parr (0+) | 2004 | 2005 | adipose clip | Mact. | 71,862 | | | | | | | |
| Unfed fry (0+) | 2000 | 2001 | unmarked | Mact. | 23,370 | | | 669 | 166 | 835 | 3.6% | |
| Unfed fry (0+) | 2000 | 2001 | unmarked | Minto | 162,153 | | | 2,901 | 940 | 3,841 | 2.4% | |
| Unfed fry (0+) | 2000 | 2001 | unmarked | Mact. + Minto | 185,523 | | | 3,570 | 1,106 | 4,676 | 2.5% | |
| Unfed fry (0+) | 2001 | 2002 | unmarked | Mact. | 138,682 | | | 1,879 | | 1,879 | 1.4% | * |
| Unfed fry (0+) | 2002 | 2003 | unmarked | Mact. | 296,818 | | | | | | | |
| Unfed fry (0+) | 2003 | 2004 | unmarked | Mact. | 369,109 | | | | | | | |
| Unfed fry (0+) | 2004 | 2005 | unmarked | Mact. | 258,873 | | | | | | | |

*Notes:*

*2002 smolt class*

*2003 smolt class*

*2004 smolt class*

*2005 smolt class*

** preliminary analysis; data not complete*

**Table 3:** **Locus variability, exclusion power and source of microsatellite genetic markers used in parentage analysis of Big Salmon River smolts.**

| Microsatellite locus | No. alleles | Ho | He | Exclusion power | Reference |
|---|---|---|---|---|---|
| **2210** | 13 | 70.6 | 74.0 | 0.354 | Paterson et al. (2004) |
| **1605** | 16 | 77.3 | 77.0 | 0.543 | Paterson et al. (2004) |
| **2215** | 21 | 84.9 | 84.8 | 0.637 | Paterson et al. (2004) |
| **2216** | 18 | 90.2 | 87.1 | 0.782 | Paterson et al. (2004) |
| **1G7** | 16 | 92.2 | 88.8 | 0.811 | Paterson et al. (2004) |
| **Ssa197** | 14 | 86.9 | 86.4 | 0.675 | O'Reilly et al. (1996) |
| **Ssa202** | 19 | 91.5 | 89.3 | 0.816 | O'Reilly et al. (1996) |

*Ho = Observed heterozygosity*
*He = Expected heterozygosity*
*Exclusion power = proportion of crosses excluded as candidate parents for a given locus*

**Table 4:** **Sample information for smolts captured and analyzed from the Big Salmon River in 2003 and 2004.**

| Year of capture | Number of smolts to Mactaquac (LGB) | Carlin tag series | No. smolts analyzed | No. smolts analyzed at 6/6+ microsatellite loci |
|---|---|---|---|---|
| **2003** | 223 | D101-D308 | 208 | 206 |
| **2004** | 130 | A700-A818 | 119 | 108 |
| **2005*** | 77 | - | - | - |

** sample information from LGB at Mactaquac not available at time of publication*

**Table 5:** **Background information on candidate crosses against which smolts collected from the Big Salmon River in 2003 and 2004 were tested.**

| Parental cross group | Generations of captive rearing | No. crosses | Year of capture (smolt age) |
|---|---|---|---|
| **BSR Mactaquac 2000** | >1 | 87 | 2003, 2004 (age-2 and age-3) |
| **BSR Minto 2000** | 1-2 | 145 | 2003, 2004 (age-2 and age-3) |
| **BSR Total (2000)** | | 232 | n/a |
| **BSR Mactaquac 2001** | >1 | 122 | 2004 (age-2) |
| **BSR Minto 2001*** | 1-2 | 9 | 2004 (age-2) |
| **BSR Total (2001)** | n/a | 131 | n/a |
| **BSR Grand Total** | n/a | 363 | n/a |

** BSR Minto 2001 progeny NOT released as unfed fry and therefore NOT available for capture as $LGB_{fry}$ smolts*

**Table 6:** **Annual rotary screw trap catch, capture efficiency, origin and age proportions for Big Salmon River Atlantic salmon smolts, 2001 - 2005.**

| Year | Smolt origin | Catch | No. marked | No. recaps | Capture efficiency (recaps / marked) | Proportion of catch (wild & $LGB_{parr}$ only) | Proportion of catch by age | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 | 4 |
| 2001* | wild | 691 | 360 | 23 | 6.39 | 1.00 | 0 | 0.95 | 0.05 | 0 |
| 2002 | wild | 439 | 84 | 9 | 10.71 | 0.68 | 0 | 0.73 | 0.26 | 0.01 |
| | $LGB_{parr}$ | 208 | 34 | 3 | 8.82 | 0.32 | 1.00 | - | - | - |
| | combined | 647 | 118 | 12 | 10.17 | - | - | - | - | - |
| 2003 | wild | 1,071 | 841 | 98 | 11.65 | 0.70 | 0 | 0.89 | 0.10 | 0.01 |
| | $LGB_{parr}$ | 458 | 441 | 33 | 7.48 | 0.30 | 0.80 | 0.20 | - | - |
| | combined | 1,529 | 1282 | 131 | 10.22 | - | - | - | - | - |
| 2004 to June 17 | wild | 326 | 180 | 9 | 5.00 | 0.79 | - | - | - | - |
| | $LGB_{parr}$ | 84 | 54 | 4 | 7.41 | 0.21 | - | - | - | - |
| | combined | 410 | 234 | 13 | 5.56 | - | - | - | - | - |
| 2004 post June 17 | wild | 35 | 12 | 6 | 50.00 | 0.33 | - | - | - | - |
| | $LGB_{parr}$ | 72 | 25 | 9 | 36.00 | 0.67 | - | - | - | - |
| | combined | 107 | 37 | 15 | 40.54 | - | - | - | - | - |
| 2004 Total | wild | 361 | 192 | 15 | 7.81 | 0.70 | 0 | 0.70 | 0.30 | 0 |
| | $LGB_{parr}$ | 156 | 79 | 13 | 16.46 | 0.30 | 0.84 | 0.16 | 0 | 0 |
| | combined | 517 | 271 | 28 | 10.33 | - | - | - | - | - |
| 2005 | wild | 444 | 266 | 26 | 9.97 | 0.51 | 0 | 0.77 | 0.22 | 0.01 |
| | $LGB_{parr}$ | 428 | 342 | 35 | 10.23 | 0.49 | 0.70 | 0.28 | 0.02 | 0 |
| | combined | 872 | 608 | 63 | 10.36 | - | - | - | - | - |

**Upper RST catches (Bridge Pool – 152, Lodge Pool – 224) and Lower RST catches (Amateur Pool – 315) combined*

**Table 7:** **Lengths and weights ± standard deviation of wild and $LGB_{parr}$ Atlantic salmon smolts sampled (n) from the Big Salmon River, 2001 - 2005.**

| Year | Wild | | | | | $LGB_{parr}$ | | |
|---|---|---|---|---|---|---|---|---|
| | Age-2 | Age-3 | Age-4 | No Age | Overall | Age-1 | Age-2 | Age-3 |
| *Length (cm)* | | | | | | | | |
| 2001 A | 14.3 ± 1.1 (29) | 20.7 (1) | (0) | 14.1 ± 1.4 (121) | 14.3 ± 1.5 (151) | n/a | n/a | n/a |
| 2001 B | 15.3 ± 1.3 (29) | 18.9 ± 0.7 (2) | (0) | 14.9 ± 1.2 (193) | 14.9 ± 1.2 (224) | n/a | n/a | n/a |
| 2001 (A+B) | 14.8 ± 1.3 (58) | 19.5 ± 1.2 (3) | (0) | 14.7 ± 1.3 (314) | 14.9 ± 1.4 (375) | n/a | n/a | n/a |
| 2001 C | 16.4 ± 0.9 (101) | 17.6 ± 0.6 (5) | 19.5 (1) | 15.1 ± 1.1 (227) | 15.5 ± 1.3 (334) | n/a | n/a | n/a |
| 2002 | 14.9 ± 1.0 (59) | 15.6 ± 1.2 (21) | 19.2 (1) | 16.5 ± 1.6 (82) | 15.8 ± 1.5 (163) | n/a | n/a | n/a |
| 2003 | 14.8 ± 1.1 (194) | 15.7 ± 1.2 (23) | 17.9 ± 0.6 (2) | 14.0 (1) | 14.9 ± 1.2 (220) | 13.7 ± 1.0 (90) | 14.5 ± 0.9 (22) | n/a |
| 2004 | 14.8 ± 1.4 (89) | 16.0 ± 1.4 (38) | (0) | 17.0 ± 1.4 (2) | 15.2 ± 1.5 (129) | 13.6 ± 1.0 (43) | 13.6 ± 1.0 (8) | (0) |
| 2005 | 14.6 ± 1.4 (85) | 15.5 ± 1.8 (24) | 16.7 (1) | 15.1 (1) | 14.8 ± 1.5 (111) | 13.0 ± 1.5 (76) | 14.0 ± 1.3 (30) | 14.2 ± 1.7 (2) |
| *Weight (grams)* | | | | | | | | |
| 2001 A | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 2001 B | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| 2001 C | 45.3 ± 6.8 (98) | 54.9 ± 5.5 (5) | 69.5 (1) | 34.0 ± 6.6 (152) | 38.9 ± 9.1 (256) | n/a | n/a | n/a |
| 2002 | 31.4 ± 6.3 (58) | 36.0 ± 8.3 (20) | 55.7 (1) | 42.8 ± 11.8 (80) | 37.9 ± 11.1 (159) | 25.6 ± 4.9 (42) | n/a | n/a |
| 2003 | 32.6 ± 7.7 (192) | 37.3 ± 9.7 (21) | 56.5 ± 2.1 (2) | 23.5 (1) | 33.2 ± 8.3 (216) | 23.8 ± 5.7 (88) | 29.0 ± 5.7 (20) | n/a |
| 2004 | 33.6 ± 9.1 (89) | 40.5 ± 11.1 (38) | 0 | 0 | 35.9 ± 10.4 (129) | 25.5 ± 6.1 (43) | 25.4 ± 5.2 (8) | 0 |
| 2005 | 30.2 ± 8.0 (85) | 36.0 ± 12.4 (24) | 42.1 (1) | 43.0 (1) | 31.6 ± 9.4 (111) | 19.0 ± 4.8 (76) | 25.8 ± 7.0 (30) | 25.8 ± 9.4 (2) |

*Note: A- Bridge Pool; B- Lodge Pool; C- Amateur Pool*

**Table 8:** **Annual mean condition factors (sample size in brackets) for wild and $LGB_{parr}$ Atlantic salmon smolts from the Big Salmon River, 2001 - 2005.**

| Wild | | | | | | $LGB_{parr}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | Year | | | | | Age | Year | | | |
| | 2001 | 2002 | 2003 | 2004 | 2005 | | 2002 | 2003 | 2004 | 2005 |
| | | | | | | 1 | 0.88 (42) | 0.92 (88) | 1.00 (43) | 0.90 (76) |
| 2 | 1.01 (98) | 0.94 (58) | 0.99 (192) | 1.01 (89) | 0.96 (85) | 2 | - | 0.94 (20) | 1.00 (8) | 0.93 (30) |
| 3 | 1.01 (5) | 0.96 (20) | 0.95 (21) | 0.97 (38) | 0.93 (24) | 3 | - | - | (0) | 0.88 (2) |
| 4 | 0.94 (1) | 0.79 (1) | 0.99 (2) | 0 | 0.91 (1) | 4 | - | - | - | (0) |
| **Total** | 1.01 (104) | 0.94 (79) | 0.98 (215) | 1.00 (127) | 0.95 (110) | **Total** | 0.88 (42) | 0.92 (108) | 1.00 (51) | 0.91 (108) |

**Table 9:** **Annual summary of other aquatic species captured in the Big Salmon River rotary screw trap, 2001 - 2005.**

| Year | American eel | Minnow sp. | Brook Trout | Rainbow Trout | Gaspereau | Others |
|---|---|---|---|---|---|---|
| 2001* | 29 | 182 | 4 | 2 | 0 | 27 |
| 2002 | 525 | 511 | 7 | 4 | 1 | 2 |
| 2003 | 242 | 43 | 6 | 4 | 16 | 0 |
| 2004 | 365 | 1,336 | 6 | 5 | 17 | 2 |
| 2005 | 296 | 223 | 8 | 3 | 12 | 31 |

*Note:* ** includes catches from the rotary screw trap at Hearst Pool and Bridge Pool (combined) only*
*'Minnow sp.' includes dace, shiners and chubs*
*'Others' includes sticklebacks, shad, banded killifish, frog and salamander*

**Table 10:** **Results of microsatellite-based parentage analyses, where BSR Minto and BSR Mactaquac candidate parents are tested against smolts captured in the Big Salmon River in 2003 and 2004.**

| | Likely Parental Cross Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Smolt group by year** | **BSR Mact. 2000 (%)** | **BSR Minto 2000 (%)** | **BSR Mac. + Minto (LGB origin, 2000) (%)** | **BSR Mact. 2001 (%)** | **BSR Minto 2001 (%)** | **BSR Mact. + Minto (LGB origin, 2001) (%)** | **BSR Mact. total (%)** | **BSR Minto total (%)** | **BSR Mact. + Minto (LGB origin, all years) (%)** | **Wild prod. (%)** |
| **BSR 2003 captured smolts (N=206)** | 15 (7.3) | 65 (31.6) | 80 (38.8) | N/A | N/A | N/A | 15 (7.3) | 65 (31.6) | 80 (38.8) | 126 (61.2) |
| **BSR 2004 captured smolts (N=108)** | 3 (2.8) | 17 (15.7) | 20 (18.5) | 34 (31.5) | 0 (0) | 34 (31.5) | 37 (34.3) | 17 (15.7) | 54 (50) | 54 (50) |
| **BSR 2003+2004 captured smolts (N=314)** | 18 (5.7) | 82 (26.1) | 100 (31.9) | 34 (10.8) | 0 (0) | 34 (10.8) | 52 (16.6) | 82 (26.1) | 134 (42.7) | 180 (62.1) |

*BSR Mact.* = *offspring created through artificial spawning of BSR parents in captivity at Mactaquac, released into the BSR as unfed fry, and recovered as smolts prior to migration to sea*

*BSR Minto* = *offspring created through artificial spawning of BSR parents in captivity at Minto, released into the BSR as unfed fry, and recovered as smolts prior to migration to sea*

*Wild prod.* = *smolts captured from the Big Salmon River in 2003 and 2004 that could not be assigned to Mactaquac or Minto parents at the suite of microsatellites used here*

**Table 11: Annual number and rotary screw trap capture efficiency of garment-tagged (2002 & 2003 only) and untagged $LGB_{smolt}$'s released upriver of the rotary screw trap in the Big Salmon River, 2001 - 2005.**

| Year | Color garment tag | No. released | Date released | No. recaptured | Capture efficiency (%) (recaps / marked) |
|---|---|---|---|---|---|
| 2001 | none | - | - | - | - |
| 2002 | blue | 500 | April 30 | 6 | 1.20 |
| | clear | 500 | May 06 | 5 | 1.00 |
| | green | 500 | May 13 | 11 | 2.20 |
| | red | 500 | May 21 | 17 | 3.40 |
| | black | 500 | May 27 | 4 | 0.80 |
| | yellow | 500 | June 03 | 7 | 1.40 |
| | combined | 3,000 | - | 50 | 1.67 |
| | untagged | 8,425* | - | 76 | 0.90 |
| 2003 | clear | 534 | May 14 | 16 | 3.00 |
| | green | 500 | May 21 | 21 | 4.20 |
| | red | 492 | May 27 | 21 | 4.27 |
| | blue | 490 | June 02 | 28 | 5.71 |
| | combined | 2,016 | - | 86 | 4.27 |
| | untagged | 11,631 | - | 496 | 4.26 |
| 2004 | untagged | 13,224 | - | 261 | 1.97 |
| 2005 | untagged | 1,296 | June 01 & 02 | 33 | 2.55 |

**total untagged smolts released is 16,725; 8,300 smolts were released down river of the RST and NOT available for recapture*

**Table 12: Population estimates (2.5 and 97.5 percentiles) by age class for wild and $LGB_{parr}$ Atlantic salmon smolts from the Big Salmon River, 2001 - 2005.**

| Year | Smolt origin | Estimate (2.5 and 97.5 percentiles) | Estimates by age | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| 2001 | wild | 5,290 (3,820 – 8,620) | 0 | 5,026 | 264 | 0 |
| 2002 | wild | 4,295 (2,775 – 9,282) | 0 | 3,128 | 1,114 | 53 |
| | $LGB_{parr}$ | 2,035 (1,315 – 4,398) | 2,035 | 0 | 0 | 0 |
| 2003 | wild | 9,200 (7,725 – 11,325) | 0 | 8,150 | 966 | 84 |
| | $LGB_{parr}$ | 6,120 (4,620 – 9,060) | 4,918 | 1,202 | 0 | 0 |
| 2004 | wild | 5,969 (3,927 – 11,944) | 0 | 4,197 | 1,772 | 0 |
| | * $LGB_{parr}$ | 1,691 (1,118 – 3,366) | 1,426 | 265 | 0 | 0 |
| 2005 | wild | 4,550 (3,325 – 7,125) | 0 | 3,525 | 984 | 41 |
| | * $LGB_{parr}$ | 4,175 (3,175 – 6,100) | 2,938 | 1,160 | 77 | 0 |

** includes $LGB_{parr}$ released in fall and spring*

**Figure 1: Map of Big Salmon River, New Brunswick showing rotary screw trap locations from 2001 to 2005.**

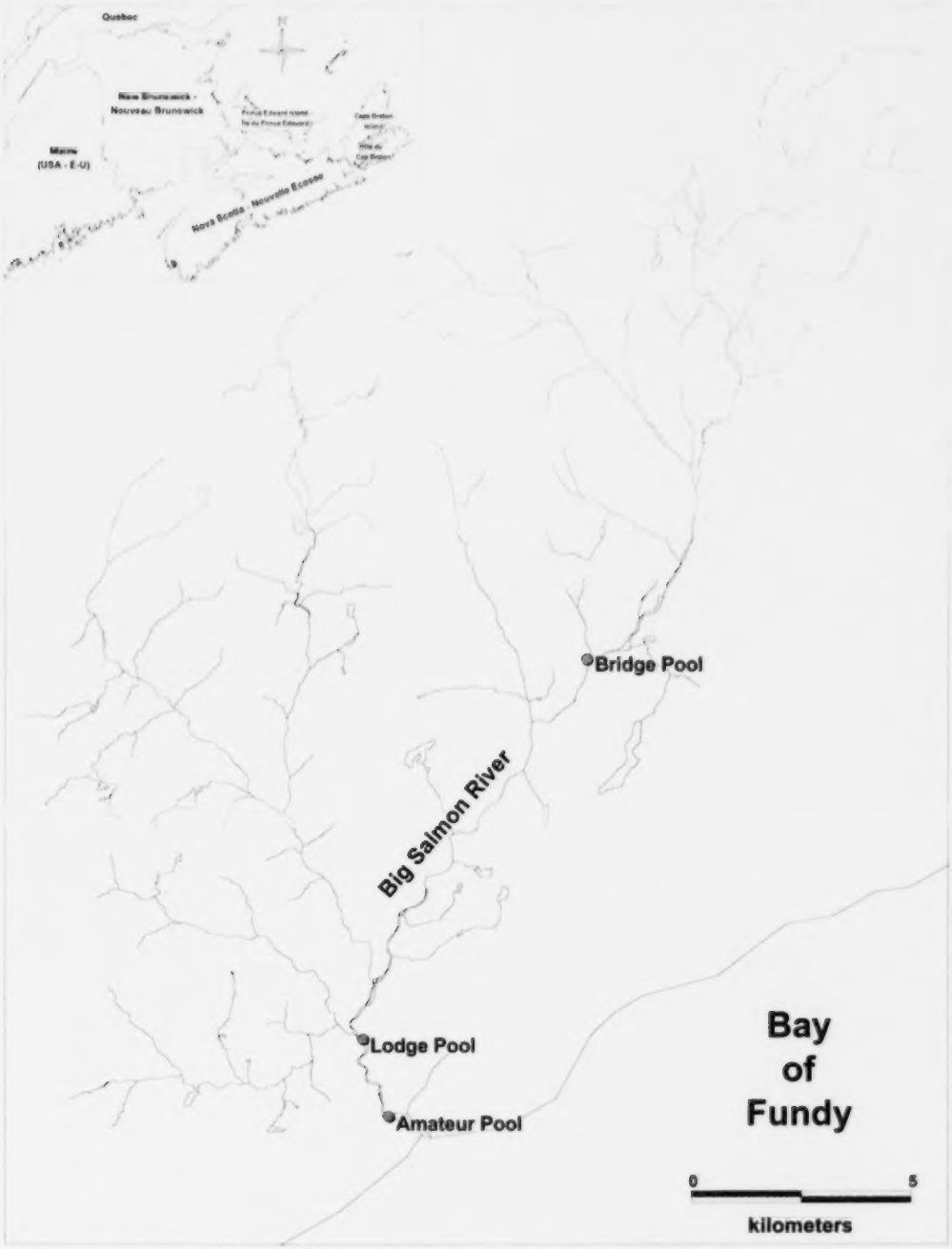


**Figure 2: Photo of rotary screw trap (RST) used in the Big Salmon River, 2001 - 2005.**

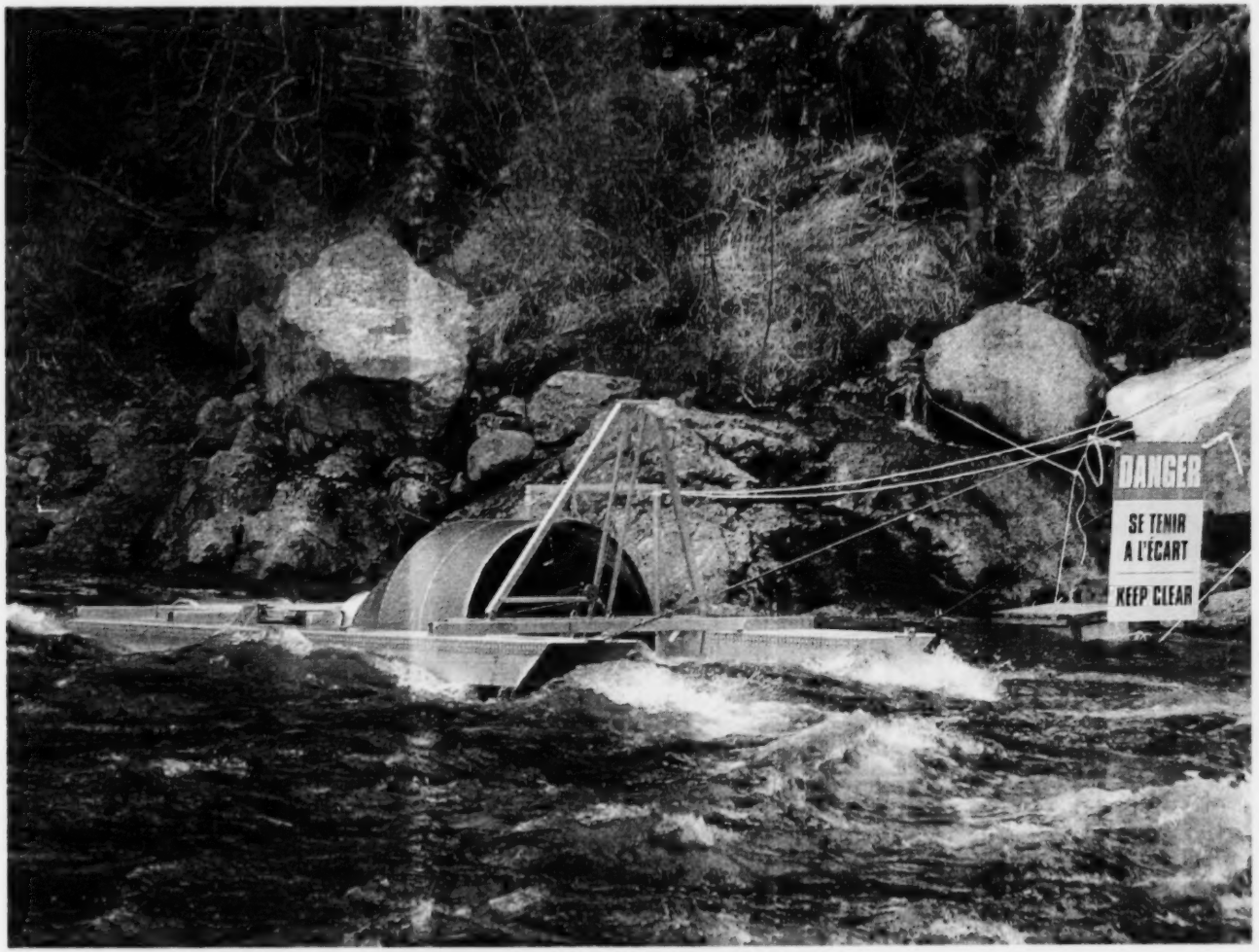


**Figure 3: Laboratory steps associated with the analysis of microsatellite variation (a) and strategies employed to minimize and quantify genotyping errors (b).**

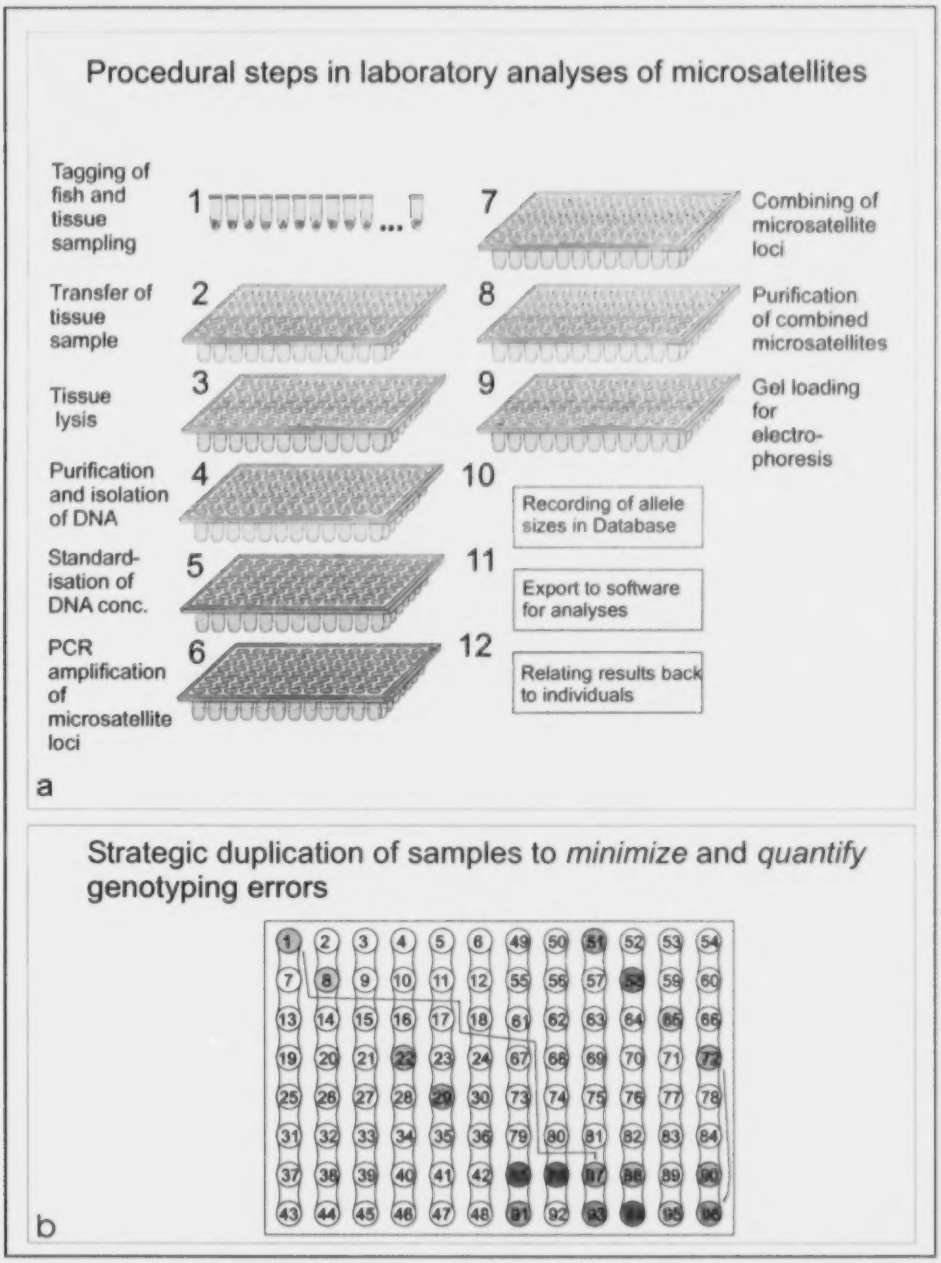


**Figure 4:** **Daily proportion of total smolt catch and mean daily water temperature in the Big Salmon River, 2001 - 2005. Wild - solid black bar, $LGB_{parr}$ - clear bar and $LGB_{smolt}$ - hatched bar. Only wild smolts were caught in 2001 and were grouped based on upper rotary screw trap catches (grey bar) and lower rotary screw trap catches (spotted bar).**

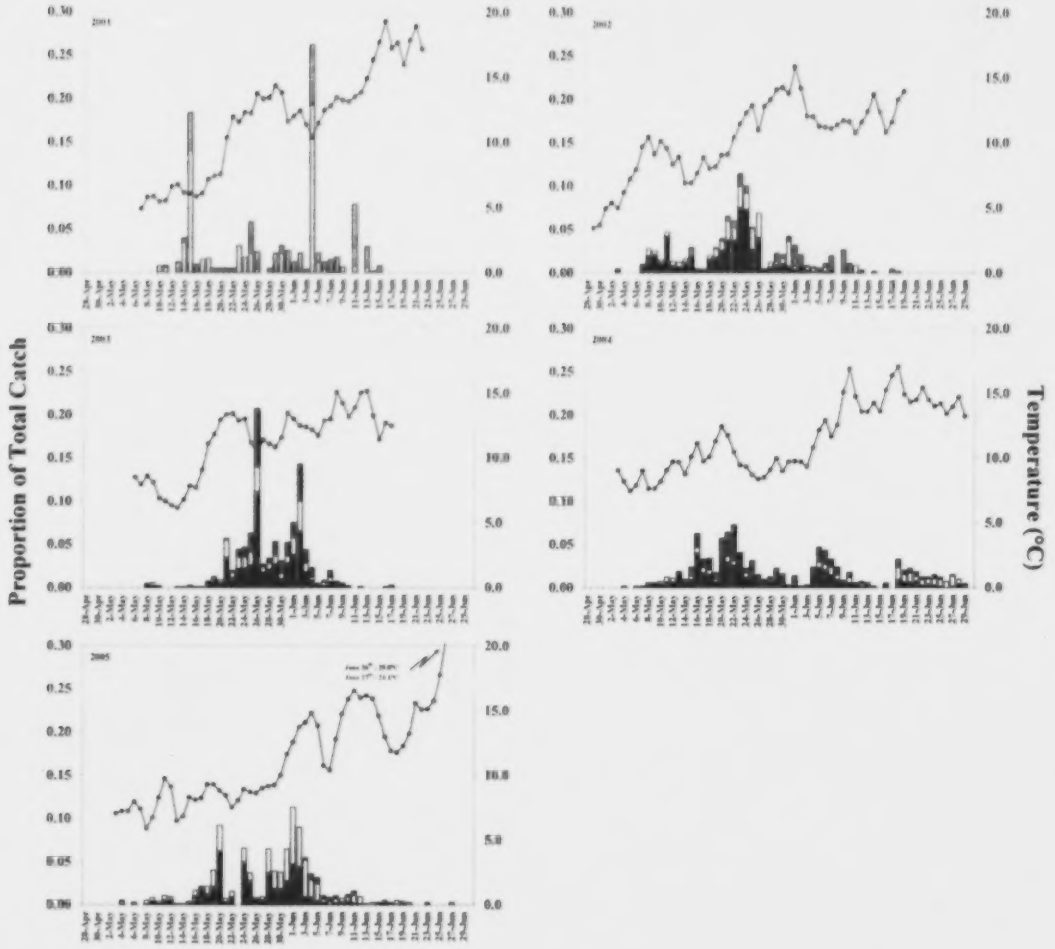


**Figure 5:** **Distribution of smolt captures by date and year; showing the first and last smolts captured as well as the 10%, 50% and 90% cumulative proportion of catch. (A) Comparison of wild smolt captures from 1966-1972 (from Jessop, 1975) and from 2001-2005; (B) wild and $LGB_{parr}$ smolt captures in the Big Salmon River, 2002-2005.**

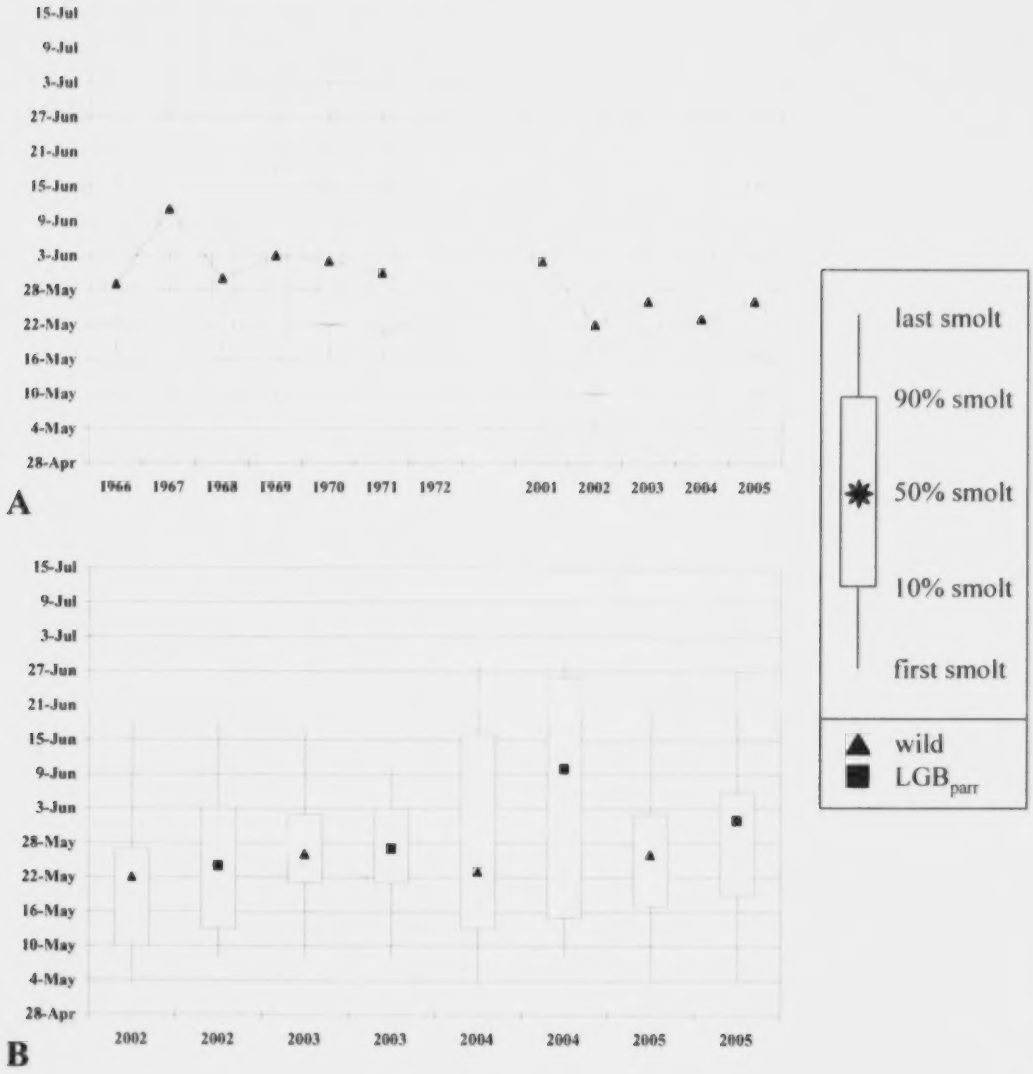


**Figure 6: Annual length-weight relationships for wild and $LGB_{parr}$ smolts from the Big Salmon River, 2001 – 2005.**

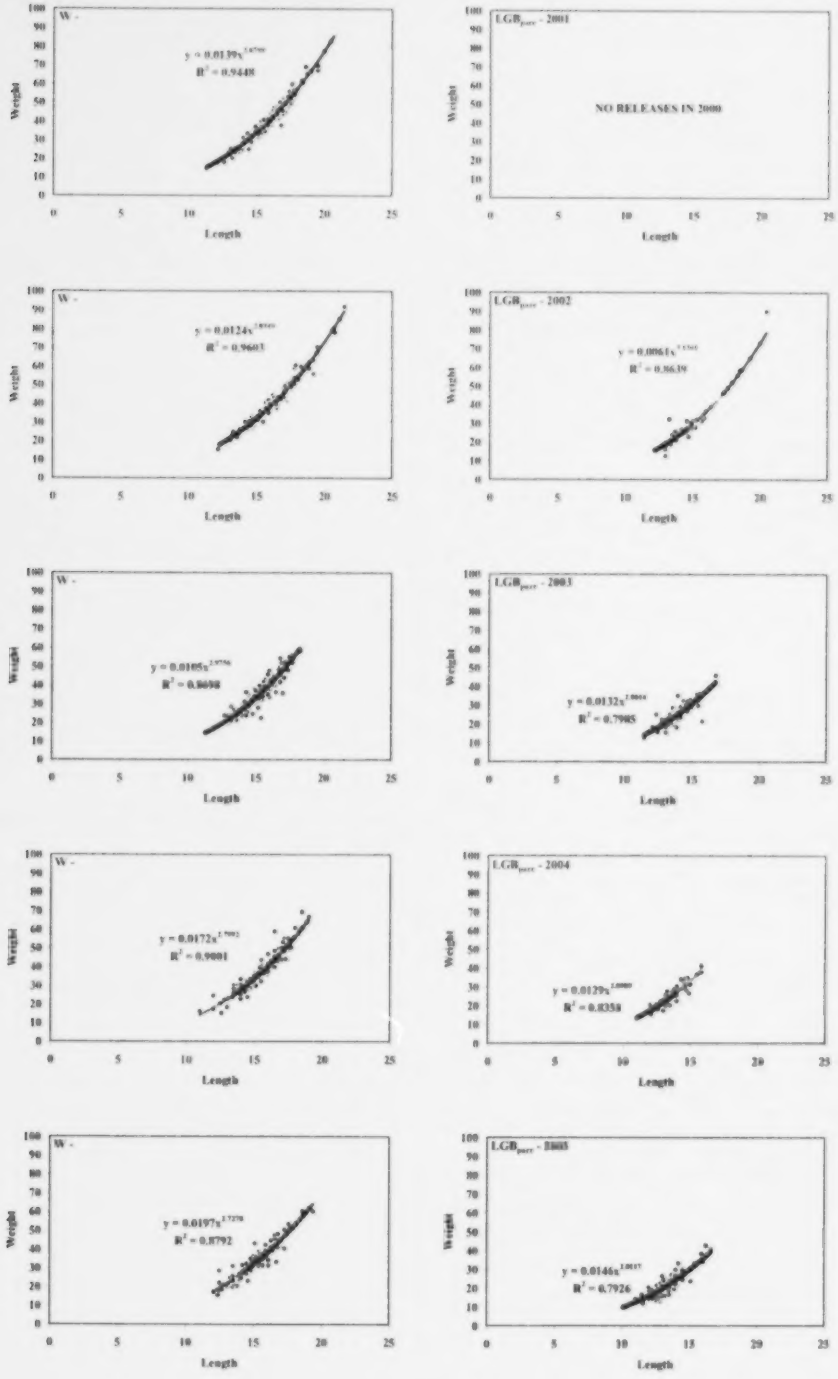


**Figure 7:** **Daily rotary screw trap speed (revolutions per minute) at time of fishing for the years 2001 to 2005. Gaps indicate rotary screw trap speed was not recorded for that day. Speeds recorded in 2001 were from the upper rotary screw trap's only. The arrow indicates the relocation of the rotary screw trap on June 17, 2004.**

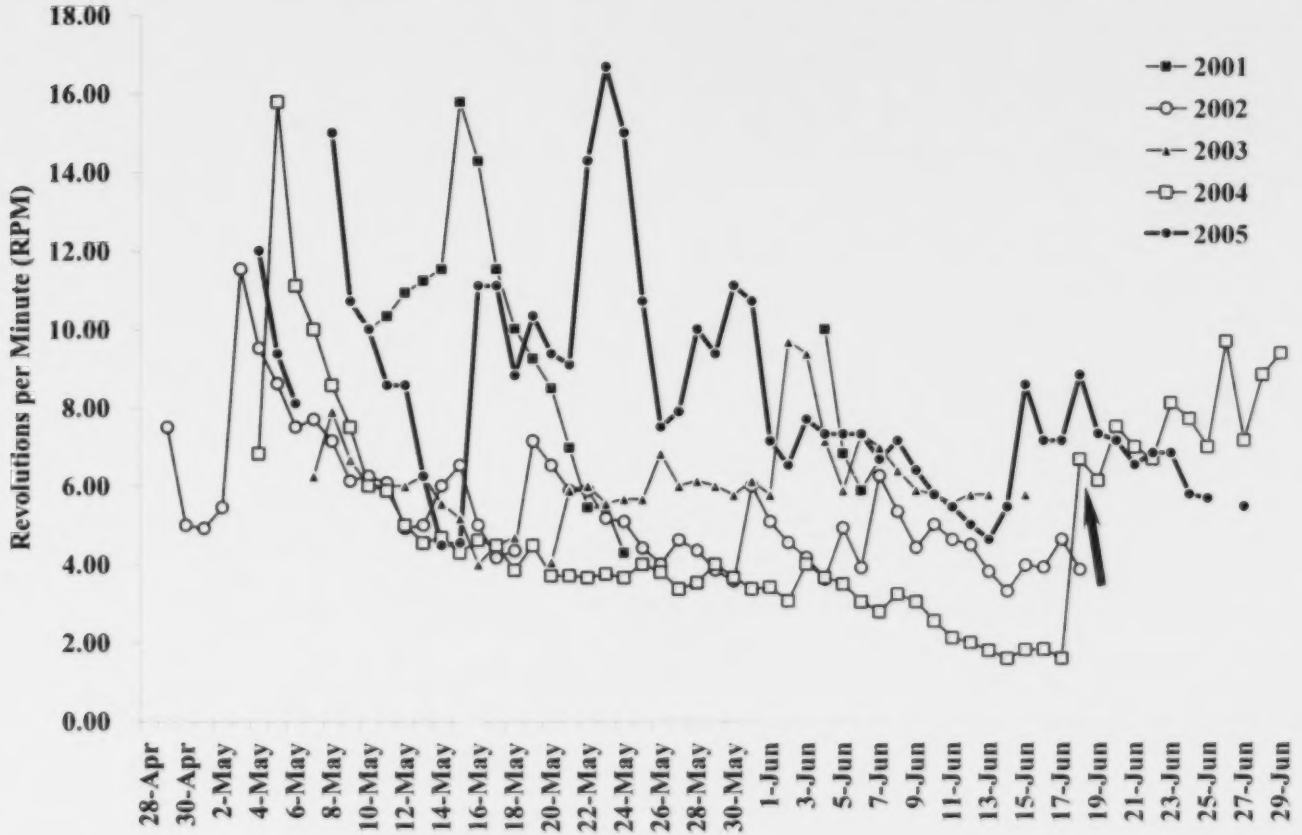
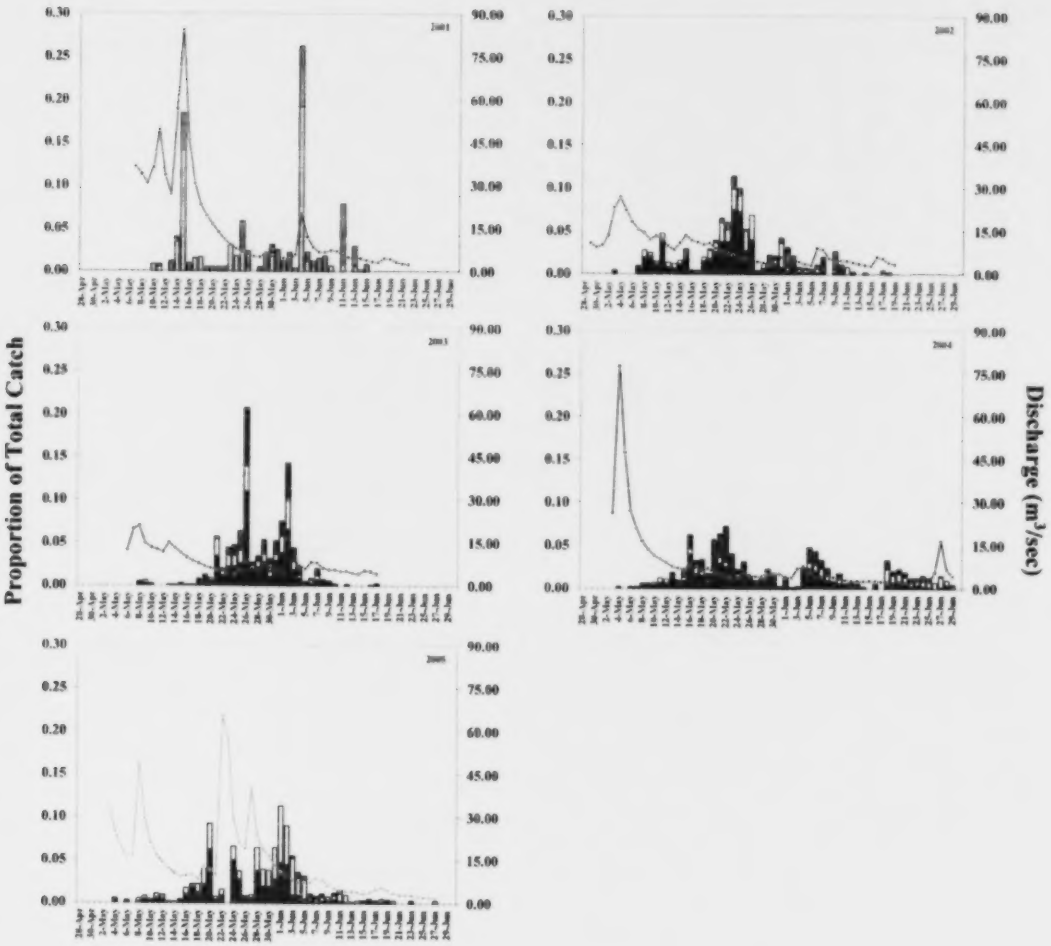


**Figure 8:** **Daily proportion of total smolt catch in the Big Salmon River and mean daily discharge from the nearby Point Wolfe River, 2001 – 2005. wild - solid black bar, $LGB_{parr}$ - clear bar and $LGB_{smolt}$ - hatched bar. Only wild smolts were caught in 2001 and were grouped by Upper RST catches (grey bar) and Lower RST catches (spotted bar). Discharge data provided by Environment Canada; 2005 data is preliminary, not verified or adjusted.**



**Appendix I: Daily catch summary of smolts captured in the rotary screw trap(s), Big Salmon River, 2001 – 2005. Shaded areas – rotary screw trap not checked; boxed numbers – some origins adjusted after scale analysis. In 2001 rotary screw traps were operated at Amateur Pool (lower) and at Bridge and Lodge pools (upper). From 2002-2005 the rotary screw trap was operated at Amateur Pool.**

| | | 2001 | | 2002 | | | 2003 | | | 2004 | | | 2005 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Day | upper | lower | wild | $LGB_{parr}$ | $LGB_{smolt}$ | wild | $LGB_{parr}$ | $LGB_{smolt}$ | wild | $LGB_{parr}$ | $LGB_{smolt}$ | wild | $LGB_{parr}$ | $LGB_{smolt}$ |
| April | 28 | | | | | | | | | | | | | | |
| April | 29 | | | | | | | | | | | | | | |
| April | 30 | | | 0 | 0 | 0 | | | | | | | | | |
| May | 01 | | | 0 | 0 | 0 | | | | | | | | | |
| May | 02 | | | 0 | 0 | 0 | | | | | | | | | |
| May | 03 | | | 3 | 0 | 0 | | | | 0 | 0 | 0 | | | |
| May | 04 | | | | | | | | | 1 | 0 | 0 | 3 | 1 | 0 |
| May | 05 | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 06 | | | | | | | | | 1 | 0 | 0 | 1 | 1 | 0 |
| May | 07 | | | 6 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | | | |
| May | 08 | | | 15 | 6 | 0 | 7 | 1 | 0 | 3 | 1 | 0 | 1 | 3 | 0 |
| May | 09 | | | 16 | 3 | 0 | 5 | 6 | 0 | 3 | 1 | 0 | 4 | 3 | 0 |
| May | 10 | 5 | 0 | 9 | 2 | 0 | 2 | 1 | 0 | 3 | 2 | 0 | 2 | 1 | 0 |
| May | 11 | 4 | 1 | 32 | 4 | 0 | 0 | 0 | 0 | 5 | 4 | 0 | 5 | 4 | 0 |
| May | 12 | 0 | 0 | 6 | 4 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 5 | 3 | 0 |
| May | 13 | 0 | 8 | 5 | 4 | 0 | 1 | 0 | 0 | 13 | 1 | 0 | 1 | 0 | 0 |
| May | 14 | 24 | 3 | 9 | 3 | 0 | 1 | 0 | 0 | 3 | 1 | 3 | 0 | 1 | 0 |
| May | 15 | 97 | 30 | 14 | 0 | 8 | 0 | 0 | 4 | 7 | 3 | 8 | 2 | 1 | 0 |
| May | 16 | 1 | 5 | 3 | 0 | 0 | 1 | 0 | 0 | 31 | 5 | 12 | 9 | 6 | 0 |
| May | 17 | 10 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 13 | 5 | 7 | 17 | 2 | 0 |
| May | 18 | 11 | 0 | 12 | 3 | 0 | 13 | 1 | 1 | 12 | 4 | 10 | 11 | 8 | 0 |
| May | 19 | 0 | 3 | 14 | 7 | 1 | 21 | 3 | 1 | 5 | 2 | 6 | 19 | 17 | 0 |
| May | 20 | 0 | 3 | 20 | 8 | 2 | 12 | 6 | 0 | 28 | 2 | 14 | 56 | 27 | 0 |
| May | 21 | 0 | 3 | 29 | 17 | 4 | 74 | 41 | 3 | 23 | 5 | 21 | 3 | 3 | 0 |
| May | 22 | 0 | 3 | 29 | 11 | 6 | 24 | 12 | 4 | 20 | 4 | 32 | 8 | 6 | 0 |
| May | 23 | 21 | 0 | 58 | 19 | 11 | 46 | 27 | 19 | 14 | 1 | 16 | | | |
| May | 24 | 12 | 0 | 56 | 15 | 6 | 47 | 27 | 24 | 9 | 4 | 4 | 45 | 14 | 0 |
| May | 25 | 15 | 25 | 21 | 18 | 1 | 55 | 31 | 46 | 12 | 2 | 10 | 25 | 8 | 0 |
| May | 26 | 3 | 13 | 31 | 22 | 0 | 233 | 61 | 142 | 7 | 1 | 3 | 5 | 2 | 0 |
| May | 27 | 0 | 0 | 3 | 0 | 0 | 37 | 12 | 7 | 1 | 0 | 6 | 5 | 3 | 0 |
| May | 28 | 0 | 3 | 5 | 4 | 0 | 45 | 14 | 12 | 2 | 1 | 6 | 34 | 24 | 0 |
| May | 29 | 0 | 15 | 7 | 3 | 7 | 58 | 19 | 34 | 9 | 0 | 8 | 17 | 18 | 0 |
| May | 30 | 15 | 6 | 8 | 5 | 3 | 21 | 13 | 31 | 6 | 0 | 6 | 17 | 17 | 0 |
| May | 31 | 0 | 17 | 5 | 23 | 4 | 61 | 15 | 33 | 2 | 0 | 0 | 25 | 33 | 0 |
| June | 01 | 0 | 8 | 3 | 3 | 18 | 80 | 41 | 36 | 7 | 1 | 2 | 42 | 60 | 0 |
| June | 02 | 0 | 15 | 6 | 0 | 10 | 137 | 74 | 89 | 1 | 0 | 0 | 40 | 41 | 0 |
| June | 03 | 0 | 2 | 2 | 3 | 1 | 38 | 21 | 32 | 2 | 0 | 0 | 8 | 39 | 2 |
| June | 04 | 133 | 48 | 1 | 3 | 1 | 18 | 7 | 22 | 10 | 1 | 7 | 8 | 18 | 6 |

**Appendix I: continued...**

| | | 2001 | | 2002 | | | 2003 | | | 2004 | | | 2005 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Day | upper | lower | W | $LGB_{parr}$ | $LGB_{smolt}$ | W | $LGB_{parr}$ | $LGB_{smolt}$ | W | $LGB_{parr}$ | $LGB_{smolt}$ | W | $LGB_{parr}$ | $LGB_{smolt}$ |
| June | 05 | 8 | 7 | 1 | 0 | 3 | 5 | 2 | 2 | 18 | 5 | 13 | 4 | 18 | 6 |
| June | 06 | 3 | 5 | 1 | 4 | 3 | 5 | 8 | 4 | 16 | 5 | 12 | 3 | 3 | 3 |
| June | 07 | 0 | 10 | 3 | 2 | 10 | 14 | 10 | 16 | 11 | 7 | 7 | 1 | 3 | 3 |
| June | 08 | 0 | 12 | | | | 2 | 2 | 10 | 7 | 4 | 7 | 2 | 4 | 3 |
| June | 09 | 4 | 0 | 2 | 2 | 16 | 4 | 2 | 4 | 2 | 0 | 4 | 3 | 3 | 0 |
| June | 10 | 0 | 0 | 0 | 1 | 7 | 0 | 1 | 2 | 4 | 5 | 4 | 4 | 4 | 2 |
| June | 11 | 5 | 49 | 0 | 6 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 8 | 4 |
| June | 12 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 2 | 1 | 7 | 0 |
| June | 13 | 4 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 1 | 0 |
| June | 14 | 1 | 0 | 0 | 0 | 1 | | | | 1 | 0 | 0 | 0 | 2 | 0 |
| June | 15 | 0 | 5 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| June | 16 | 0 | 0 | | | | 1 | 0 | 0 | 3 | 1 | 0 | 1 | 1 | 2 |
| June | 17 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 0 |
| June | 18 | 0 | 0 | 1 | 0 | 0 | | | | 7 | 11 | 7 | 1 | 3 | 0 |
| June | 19 | 0 | 0 | | | | | | | 5 | 7 | 3 | 2 | 1 | 0 |
| June | 20 | 0 | 0 | | | | | | | 5 | 8 | 4 | 0 | 2 | 0 |
| June | 21 | 0 | 0 | | | | | | | 6 | 4 | 4 | 0 | 0 | 0 |
| June | 22 | 0 | 0 | | | | | | | 2 | 5 | 2 | 0 | 0 | 0 |
| June | 23 | | | | | | | | | 3 | 5 | 1 | 1 | 0 | 1 |
| June | 24 | | | | | | | | | 2 | 6 | 3 | 0 | 0 | 0 |
| June | 25 | | | | | | | | | 1 | 6 | 2 | 0 | 0 | 0 |
| June | 26 | | | | | | | | | 0 | 5 | 0 | | | |
| June | 27 | | | | | | | | | 1 | 9 | 1 | 0 | 2 | 0 |
| June | 28 | | | | | | | | | 3 | 4 | 0 | | | |
| June | 29 | | | | | | | | | 0 | 2 | 1 | | | |
| June | 30 | | | | | | | | | | | | | | |
| | Totals: | 376 | 315 | 439 | 208 | 126 | 1071 | 458 | 582 | 361 | 156 | 261 | 444 | 428 | 33 |